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13CO_2 pulse labeled maize crop residues underestimate contribution to respiration of fresh and rejuvenated soils

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Farming techniques, such as the addition of crop residues to soils as mulch, are increasingly being used to improve soil carbon content. Efficiency of crop residues to store carbon belowground by evaluation of crop residue carbon loss to the atmosphere versus addition to soils can be estimated by tracing carbon contributions to both with 13C-labeled plant material. We applied maize shoot material at 2 ton/ha dry matter to incubated soils maintained at 20% gravimetric water content over a 85 d experiment and compared crop residue-derived soil respiration rates using fresh field collected Cambisol soils as well as field collected soils that were stored and either rejuvenated or not. Additionally, we compared estimates of crop residue-derived soil respiration rates using 13CO_2 pulse labeled maize that produced a heterogeneous 13C-labeled material, maize material that was continuously labeled with 13CO_2 to produce a homogenous 13C-label and unlabeled maize material. We predicted that stored soils that were rejuvenated with water to normal field gravimetric water content levels (20%) for 15 d prior to the beginning of the incubation experiment would respond to mulch application similarly to freshly collected field soils. We also predicted that heterogeneous 13C-labeled maize residues would overestimate carbon loss during the early period of decomposition and underestimate carbon loss over extended time periods.

Although freshly collected and rejuvenated soils responded similarly to mulch application, with peak respiration rates 6 d after application, fresh soils consistently respired more than rejuvenated soils by 9 to 63%, with largest respiration differences occurring 6 d after mulch application. This was supported by recovered mulch at the end of the incubation experiment, with fresh soils decomposing 90% of applied mulch compared to 59% in rejuvenated soils. Stored soils that were not rejuvenated prior to the incubation experiment had significantly higher respiration than fresh soils by 140% the day before mulch was applied to soils and 58% the day that mulch was applied. Heterogeneous 13C-labeled mulch produced CO_2 soil respiration isotope signatures similar to that of mulch within the first 3 d of application but the presence of the 13C tracer was quickly lost over time. Interestingly, the CO_2 isotope signature of soil respiration was never similar to mulch in soils treated with homogenously13C-labeled mulch. The strongest detection of the 13C tracer was observed on days 4 and 7 of the incubation experiment but was still roughly 200‰ lower than that of mulch. Contrary to our initial predictions, rejuvenation of soils only resulted in similar soil respiration trends compared to fresh soils in response to mulch application but respiration rates were still significantly lower. As predicted, heterogeneous 13C labeled mulch did not produce a lasting tracer in soil respiration compared to homogenously 13C-labeled mulch, but its signature was more pronounced during the beginning of the incubation experiment. These results suggest that rejuvenated soils are not appropriate to quantitatively estimate soil response to crop residue mulch and that estimates of carbon loss using 13C-labeled mulch must be carefully estimated depending on how the material was labeled.